0470-0024

INSTRUCTION MANUAL

REGATRON

POWER SUPPLY

MODEL 237A

SERIAL No. _____

ELECTRONIC MEASUREMENTS
COMPANY, INCORPORATED
EATONTOWN · NEW JERSEY

TELEPHONE: (201) LIberty 2-0300 TWX: (201) 542-2273 CABLE: ELMEASCO

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REGATRON®
PROGRAMMABLE
POWER SUPPLY

MODEL 237A

SERIAL No. _____

ELECTRONIC
MEASUREMENTS
COMPANY, INCORPORATED
EATONTOWN · NEW JERSEY

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Eatontown, New Jersey

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E/M* REGATRON POWER SUPPLY

MODEL 237A

TABLE OF SPECIFICATIONS

OUTPUT
0 to 300 volts, 0 to 1 ampere.

REGULATION
LINE: 0.03% or 0.03 volt, whichever is greater, for line change from 105 to 125 volts ac, 50-60 cps.
LOAD: 0.03% or 0.03 volt, whichever is greater, from no load to full load.

REGULATION WITH CHOPPER STABILIZATION
LINE OR LOAD: 0.01% or 3 millivolts, whichever is greater.

STABILITY: Within 0.01% or 50 millivolts, whichever is greater, for 8 hours after 30-minute warmup under fixed line, load, and temperature conditions, and using precision high-stability external programming resistor.

STABILITY WITH CHOPPER STABILIZATION: 0.05% + 2 millivolts, same as conditions above.

RIPPLE: 1 millivolt RMS maximum with positive or negative output grounded.

OUTPUT IMPEDANCE: Less than .01 ohm at low audio frequencies; 0.1 ohm to 10KC; 1 ohm to 40 KC.

TRANSIENT RESPONSE: For step change from no load to full or full to no load, output recovers to within dc regulation limits of initial value within 1 millisecond.

OVERVOLTAGE CAPABILITIES: Refer to paragraph 2-13.

REMOTE PROGRAMMING RESISTANCE: 1000 ohms-per-volt of output.

REMOTE SENSING: Panel terminals permit sensing of positive and negative output leads.

AMBIENT TEMPERATURE RANGE: -20°C to +45°C.

CASE GROUND POLARITY: Swinging link for positive, negative or floating output.

CIRCUIT PROTECTION: Input ac line fused, dc output fused.

TERMINATIONS: Front: Universal insulated binding posts. Rear: barrier-type terminal strips. Line cord is 3-conductor type.

CONTROLS: DC CONTROL and 30-volt VERNIER are wirewound type. Panel calibration is approximate.

MOUNTING: Unit fits 19" standard racks and is equipped with rubber feet for table mounting. Top and bottom are protected by perforated metal covers

FINISH: Smooth gray semi-gloss enamel Class 2 per MIL-E-15090.

INPUT POWER REQUIRED: 1500 watts at full load, input 125 volts ac, 60 cps.

DIMENSIONS: 10-1/2 inches high, 16-1/4 inches deep, 19 inches wide.

WEIGHT: 67 pounds, approximately.

*Registered U. S. Patent Office. Patents issued and pending.

SECTION 1

DESCRIPTION

1-1. This Regatron Programmable Power Supply is a wide-range source of voltage-regulated dc power designed for general laboratory use, for incorporation into systems, or production test applications. It is especially suitable for transistor applications requiring stable low voltages. Output is continuously adjustable from zero to maximum voltage output. A vernier permits high resolution of output down to a fraction of a volt. Further detailed performance data is presented in the Table of Specifications.

1-2. PROGRAMMING. The output voltage of this power supply can be controlled remotely, or programmed, with a resistor connected to the REM and + terminals. Output voltage then depends directly on the value of the programming resistor at a constant ratio of 1 volt per 1000 ohms. This ratio remains constant over the entire output voltage range, even at a fraction of a volt. Refer to paragraph 2-9 for instructions on programmed operation.

1-3. CONSTANT-CURRENT OUTPUT. This power supply can be converted from constant-voltage to constant-current output by means of simple external connections. Refer to paragraph 2-17.

1-4. CHOPPER STABILIZATION. This manual covers both the standard and the chopper-stabilized versions of this power supply.

SECTION 2

OPERATION

2-1. INSPECTION. Before placing the power supply in operation inspect the interior and check that all tubes are seated securely in their sockets. The top dust cover slides off towards the rear when the holding screws have been removed. Damage incurred in shipment should be handled in accordance with the instructions on the Warranty page of this manual.

2-2. INSTALLATION. This unit operates on 105 to 125 volts, 50-60 cps, single-phase ac power. It may be rack-mounted or used on a table. Top and bottom covers can be removed for increased air circulation under high ambient temperatures.

2-3. FUSES. This unit contains the following fuses mounted on the front panel:

a. F1 in the ac line input.

b. F2 in the + dc output; protects against short circuit or overloads. Replacement fuses must be of the same values as indicated on the panel.

2-4. PRELIMINARY. Before connecting ac line cord check that:

a. LINE switch is off.

b. DC switch is off.

c. DC CONTROL and VERNIER are at minimum, fully counterclockwise.

d. LOCAL/REMOTE switch is at appropriate position; LOCAL for panel control; REMOTE for remotely programmed operation.

e. Swinging link is at desired grounding position, or disconnected for floating output.

2-5. LINE AND LOAD CONNECTIONS. Connect line cord to ac power outlet. Connect load to + and — output posts. Load wires should be heavy enough to prevent substantial IR drops between output posts and load in order to maintain the specified regulation of the power supply in actual service. The remote sensing connection described in paragraph 2-7 permits compensation for IR drops in load wires.

2-6. LOCAL OPERATION.

a. Throw LINE switch on. Green indicator should light.

b. Set DC CONTROL to the desired voltage as indicated by the dial markings. This can be a coarse setting. If greater resolution is desired the VERNIER, which is additive, can provide the fine setting.

c. Turn VERNIER to precise voltage desired. For an output of 30 volts or less, set DC CONTROL to zero and select output with VERNIER alone to realize greater stability.

d. After one minute, throw DC switch on: red indicator should light. Desired voltage is now applied to load.

NOTE

Always allow a one minute warmup period from a cold start before throwing DC switch on. This switch, when off, shorts the + and — output posts, thus effectively preventing application of any excess voltages to load during warmup. Subsequently, the DC switch can be thrown on or off with no danger of exceeding the desired output voltage.

2-7. REMOTE SENSING. For remote sensing for compensation of IR drops in the output leads, throw the LOCAL/REMOTE switch to REMOTE and connect the load as shown in Figure 2-1. The sense leads should be connected to the terminals on the load in order to realize the rated regulation of the power supply at the load.

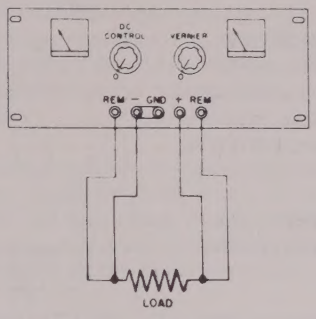


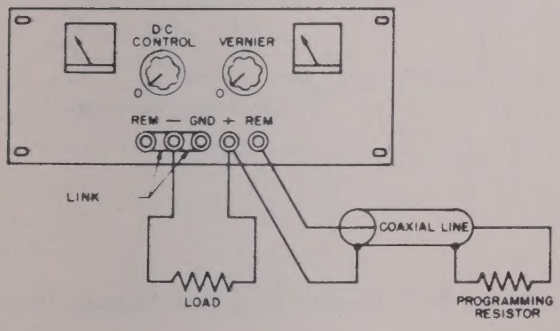
Figure 2-1. Remote Sensing Connections, Local Operation

2-8. USE OF REAR TERMINATIONS. On units equipped with rear-mounted terminations only, the preceding operation instructions apply without change. On units equipped with both front and rear terminations, the following additional procedure applies to local operation from the rear terminals:

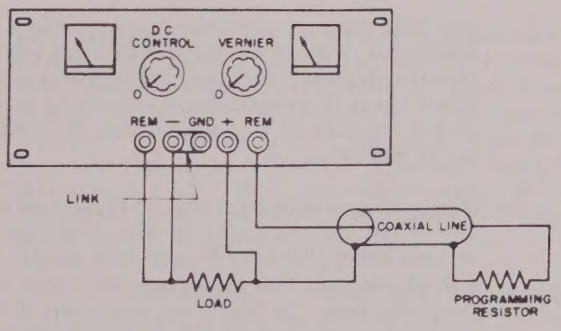
a. Throw LOCAL/REMOTE switch to REMOTE.

b. On rear terminal board, connect REM posts to adjacent output posts.

In remotely programmed use, either set of terminations can be employed in the normal manner as described in paragraphs 2-9 and 2-10. Control will then be derived from the set of terminals in use.



A. Local Sensing



B. Remote Sensing

Figure 2-2. Programmed Operation

2-9. PROGRAMMED OPERATION. As stated in paragraph 1-2, the output of this power supply can be controlled from a remote point, or programmed, with a resistor. For programmed operation, proceed as follows:

a. Throw DC and LINE switches off.

b. Throw LOCAL/REMOTE switch to REMOTE.

c. Connect the load and programming resistor as shown in Figure 2-2A. Output voltage depends on programming resistance in the ratio 1: 1000. For example, to obtain 50 volts, use a 50,000-ohm resistor.

d. Throw LINE switch on.

e. Set DC CONTROL and VERNIER to zero.

f. Throw DC switch on. Programmed voltage is now applied to load.

2-10. REMOTE SENSING, PROGRAMMED USE. Where load and control resistor are far from the unit but near each other the method of Figure 2-2B will eliminate the effect of voltage drops in the output leads, yielding remote sensing for regulation at the load.

2-11. PROGRAMMING CONSIDERATIONS. The following considerations should be carefully noted before programming this power supply:

a. An open in a remote control circuit is effectively a high programming resistance and, accordingly, will cause an uncontrolled voltage rise to maximum output. To avoid damage to the load or repeated blowing of the dc fuse, provision should be made to prevent opens. For the same reason, it is necessary that make-before-break switches be used in any multiple-voltage programming arrangement, as in Figure 2-3.

b. Unless the programming resistor itself is physically shunted across the REM and + terminal posts, it is desirable to use shielded or coaxial cable, as shown in Figure 2-2A, to prevent injection of ripple and noise from external sources. An insulated cable such as RG58/U is recommended because the coaxial sheath carries output potential.

c. For long term or permanent programmed operation, it is advisable to short out the internal controls. This will eliminate possible disturbance of programmed voltage by accidental rotation or vibration of the DC CONTROL or VERNIER.

d. Programmed operation can be combined with use of the internal controls when convenient or necessary, merely by omitting step e. of paragraph 2-9, and adjusting controls to any desired value. In this case, the value of the programming resistor will be added to the values to which the internal controls are adjusted, and the total resistance will determine output voltage.

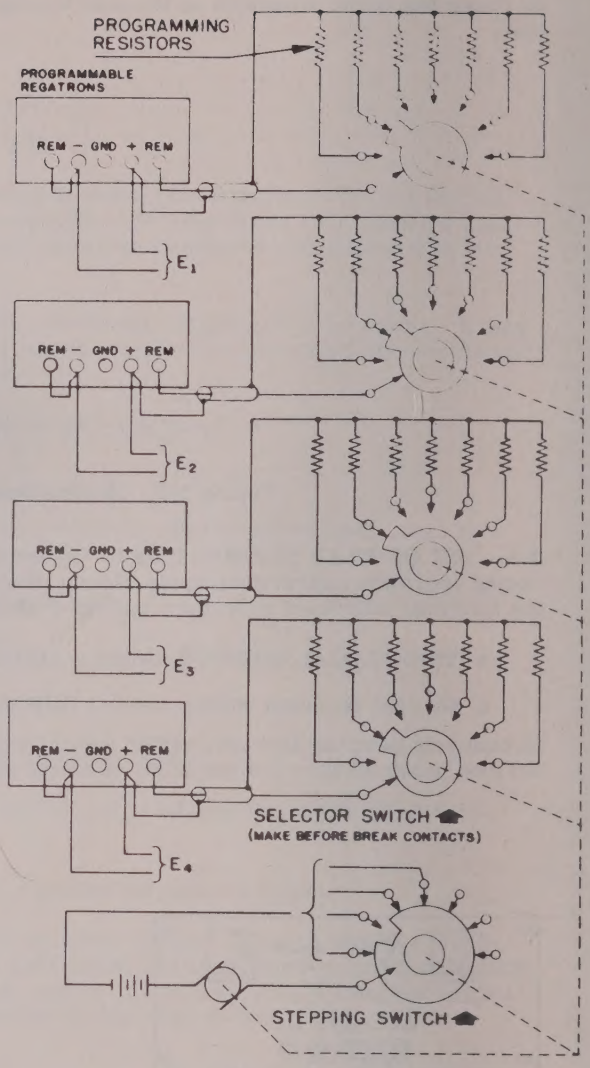


Figure 2-3. Programming With Stepping Switch

2-12. PROGRAMMING SUGGESTIONS. Although the above programming instructions are illustrated with a single fixed resistor as the remote control, it is evident that variable resistors, driven potentiometers, or fixed resistors wired to stepping switches can be employed to deliver voltages in a wide variety of time/amplitude patterns.

The time required for switching from one programmed voltage to another varies from the seconds range to the milliseconds range, depending upon conditions. Modifications for special switching times are available on special order from the factory.

It is also evident that programming can be manually or automatically actuated. As an example of automatic programming, Figure 2-3 illustrates a four level rotary switch, each level of which controls one Regatron supply. As illustrated, the entire battery can be stepped through a sequence of four programmed outputs upon command.

In an extensive system, a central board may contain the switches or rheostats for the programming of several Regatron power supplies in different locations. In such a system, it is practical to calibrate the control elements directly to dial markings. Note that the accuracy of calibration depends upon the accuracy of the resistances and/or the dial markings.

2-13. OVERVOLTAGE OPERATION. This power supply is capable of voltage output higher than the specified maximum, at reduced output current. For overvoltage an external programming resistor must be employed to substitute for or add to the resistance of the DC CONTROL and VERNIER in order to extend the control resistance range and, therefore, the output range. The overvoltage capability graph indicates the output current available at voltages beyond the rated maximum of the power supply. This graph can be obtained from the factory upon request.

2-14. REFERENCE AGING. The voltage reference tube employed in this power supply exhibits progressive change of voltage with aging, typically, 0.5% for 1000 hours of use. The resulting error at the output remains at a constant percentage throughout the voltage range of the power supply, but the absolute error varies directly with the output setting. Periodic calibration by the method described in paragraph 4-4 may be performed to eliminate any error due to aging of the reference tube.

2-15. EXTERNAL REFERENCE CONNECTION. If higher accuracy is required than is provided by the internal reference, a stable external reference source of at least 85 volts can be employed. The external reference source is connected via the rear-mounted terminal board TB1 as follows:

a. Remove the link across terminals 1 and 2 of TB1.

b. Connect the external reference across terminals 2 and 3 with the positive at terminal 3.

An external reference between 85 and 87 volts may be directly connected as described. Above 87 volts, each additional volt requires the insertion of 1000 ohms of resistance between the external reference and terminal 3 on TB1 of the power supply. Thus an external reference of — 150 volts requires a resistor of 63,000 ohms ±1%. The resistor should be a wirewound type using high stability alloy, since it directly affects the stability of the output voltage from the power supply.

2-16. USE AS VOLTAGE STANDARD. If a precision decade box is available for use as a remote programming control, this power supply will serve as a voltage standard, the accuracy of which, (neglecting aging of the reference) will be only slightly poorer than that of the decade box, even for a decade accuracy of 0.1%.

With the decade box connected as the remote programming resistor, output voltage will be indicated directly by the decade dials. Thus, the 1,000 ohms-per-step dial indicates volts, the 10,000 ohms-per-step dial indicates tens of volts, and the 100,000 ohms-per-step dial indicates hundreds of volts.

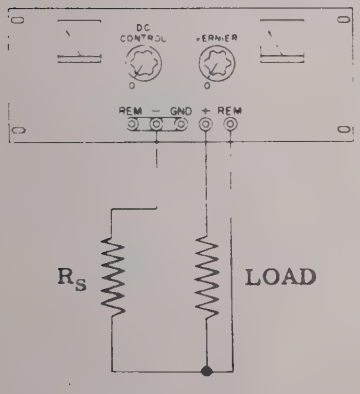


Figure 2-4
Conversion to Constant-Current Operation

In voltage-standard use, the power supply should be calibrated as described in paragraphs 4-5 and 4-6. Error due to aging of the internal reference can be nullified by periodic recalibration. If an external reference is to be employed, the calibration should be performed after connection of the external source (paragraph 2-15). It is also evident that, for minimum drift, the chopper-stabilized version of this power supply should be employed.

2-17. CONVERSION TO CONSTANT-CURRENT. For conversion from constant-voltage to constant-current output, proceed as follows:

a. Select a sample resistor, R_S in Figure 2-4, which will carry the load current and develop a sample voltage for the control system. To determine its value, select a sample voltage. 5 to 10 volts is a good range. Although the voltage may be made as high as desired it must be remembered that the sample voltage subtracts from the available output voltage. If E_S is the sample voltage and I_L is the desired load current, then $R_S = E_S/I_L$, where R_S is in ohms and I_L is in amperes. The actual wattage will be $E_S \times I_L$. The resistor used should have a somewhat higher wattage rating.

b. Make connections as shown in Figure 2-4 and set both panel controls to zero.

c. Throw LOCAL/REMOTE switch to REMOTE.

d. Throw the LINE switch on.

e. Bring current up to the desired value by turning the VERNIER up to the voltage selected as the sample in step a. above. In constant-current operation the VERNIER is the output control (for sample voltages up to 10 volts).

The conversion described above provides good dc regulation. The ac impedance of the power supply, however, is relatively low, and this should be noted in considering applications.

2-18. CHOPPER STABILIZED OPERATION. As stated in the Table of Specifications, this unit achieves regulation of 0.01% or 3 millivolts, and stability of 0.05% + 2 millivolts for 8 hours when equipped with chopper stabilization. Although both ratings are conservative, note that the stability figure is specified with the unit in programmed operation, using an external resistor of high electrical and (in the case of a variable resistor) high mechanical stability. This rating can be realized only in such operation, and with the internal controls shorted out or set to zero to prevent them from contributing variations resulting from accidental rotation or vibration.

2-19. CURRENT LIMITER. A current limiter is used to prevent an uncontrolled rise in output current from the supply in the event of a short circuit load or overload. The LIMITER CURRENT control dial markings represent the maximum current available into a short circuit load. It should be noted that in the short circuited load condition, and, actually, at load resistances approaching a short circuit, voltage output decreases and the power supply reverts, in effect, to constant-current output of moderate regulation. This changeover occurs at the so-called "knee" of the EI curve, with the quality of the amplifiers within the regulator system of the supply determining the sharpness of the "knee."

SECTION 3

CIRCUITRY

NOTE

Circuit references are made to the schematic diagram, except where indicated.

3-1. GENERAL. This power supply employs a full-wave bridge rectifier, the positive output of which is applied to series amplifiers controlled by the regulator loop. The resulting regulated dc voltage constitutes the output.

3-2. CONTROL SYSTEM, LOCAL AND PROGRAMMED. Figure 3-1 illustrates the output control configuration in simplified form. If inputs G_1 and G_2 are equal ($E_D = 0$) then:

$$\frac{E_O}{E_R} = \frac{R_1}{R_2} \text{ and } E_O = E_R \times \frac{R_1}{R_2}$$

where E_O = regulated output voltage
E_R = internal reference voltage
and R_2 is a fixed resistor.

Since E_R and R_2 are constant, $E_O = KR_1$; or, the output voltage is dependent only upon the value of R_1 which, in local operation of the power supply, consists of the DC CONTROL and VERNIER. In programmed operation, R_1 is the remote programming resistor in either local or programmed operation and the voltage output equals $0.001R_1$, or 1000-ohm control resistance per volt of output.

In practice, R_2 can be adjusted with the CAL control (on the panel) for exact 1000 ohms-per-volt programmed operation, or to calibrate output with panel dial markings.

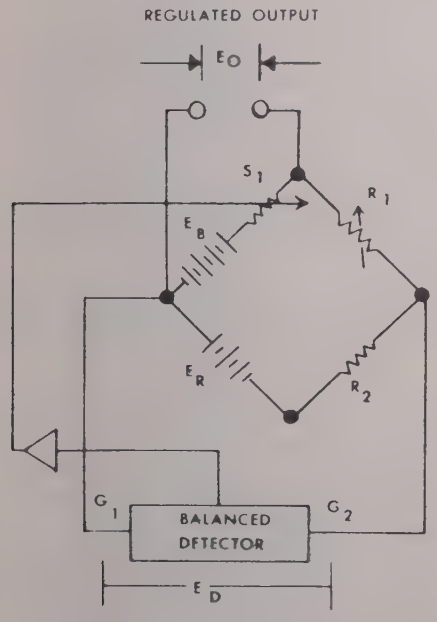


Figure 3-1. Output Control Configuration

3-3. REGULATOR SYSTEM. The regulator system employs a balanced input detector, V13, connected from the zero point of the input bleeder to the negative reference point to detect departures from balance. The amplifier error is applied to a high gain amplifier, V10, the output of which is applied to a cathode follower, V9, for sufficient current gain to drive the grids of series amplifiers V14 through V28 in such a manner as to overcome the error. Because of the high gain of the system, the error at equilibrium is very small. Reference tube V8 maintains a very stable reference potential. Gas tube V7 preregulates the potential at the cathode of V10, and gas tubes V3 through V6 maintain steady potential for the tubes of the regulator system.

3-4. UNREGULATED DC SUPPLY. A time delay relay, K1, inserted in the primary input circuit of the unregulated dc supply automatically controls warmup time for this equipment when the LINE switch is thrown, thus preventing excess voltages to the load during warmup time. Subsequently the DC switch can be on or off with no danger of exceeding the desired output voltage. The main dc supply employs silicon diodes in a full-wave bridge rectifier connection with filtering by capacitors C1 and C2. Resistors R1 and R2 are for voltage division on series connected capacitors, which discharge the filters upon turn-off of the power supply. A full-wave bridge of silicon rectifiers CR1 through CR4 comprise

the screen supply for the series amplifiers, with filtering by capacitor C4. This screen supply, the negative of which is returned to the cathodes of the series amplifiers, also serves as a plate supply for cathode follower V9 and high gain amplifier V10. Rectifiers CR9, CR10, and CR11 deliver negative dc potential for the reference system, with filtering by capacitor C7. Rectifiers CR5, CR6, and CR7 deliver positive dc potential for the plates of tube V13 and the chopper-stabilizer amplifier, when installed.

3-5. REFERENCE. The internal reference potential for the regulator of the power supply is obtained by three stages of regulation of the potential from rectifiers CR9, CR10, and CR11. The regulated -150 volts from VR tube V5 is further regulated at 108 volts by tube V6, for service at the cathodes of the balanced input detector, V13. Further preregulation at -85 volts for the cathode of amplifier V10 is accomplished by gas-filled tube V7. The stable reference potential of -85 volts utilized at the output control configuration shown in Figure 3-1 is developed by another gas-filled tube, V8. CAL control R28, in the input bridge, permits calibration of the control system to a precise output voltage based upon the exact potential across V8, and permits periodic recalibration to eliminate error resulting from aging of V8. When an external reference is employed (refer to paragraph 2-15), tube V8 is disconnected from the control system by the removal of the link across terminals 1 and 2 on TB1.

Diode CR12 functions as a one-way switch. CR12 disconnects V6 from the junction of R11 and R12 to permit momentary application of the high firing potential through R9. As soon as V6 has fired, CR12 closes the path from the junction of R11 and R12, permitting normal flow through V6 and clamping the momentary firing potential.

Positive service potentials are regulated at 150 volts by V3 and at 108 volts by V4 for application to the plates of V13. Diode CR8 functions in the same manner as CR12 for tube V4.

3-6. SERIES AMPLIFIERS. Paralleled beam power pentodes V14 through V28 are employed as series elements, or variable conductances. Control grids are direct coupled to the output of cathode follower V9. The cathodes of the series amplifiers, from which positive regulated output voltage is obtained, are removed from the + output terminal when DC switch S2 is thrown off. The DC switch also shorts the + and - terminals to protect the load from surges during standby operation. Resistor R20 provides a path for the small amount of plate current which continues to flow when the series amplifiers are biased to cutoff for zero voltage output from the power supply.

3-7. BALANCED INPUT DETECTOR. Cathode-coupled amplifier V13 is employed as a balanced input detector, grid 2 (pin 2) of which is effectively at the zero point of the control bridge (positive of the reference potential) and grid 1 (pin 7) at the other zero point on the opposite side of the control bridge. Regulated plate supply is taken from V4 and cathodes are returned through R23 to -108 volts regulated by V6. NULL control R22 permits setting of the balanced input detector to zero difference between grids. Capacitor C10 bypasses degenerative ac components appearing across R22.

Output from plate 1 (pin 6) of V13 is applied across a coupling and voltage divider network consisting of glow discharge regulator tubes V11 and V12 and resistors R17 and R19. These tubes couple plate potential to the grid of V10, maintaining a constant voltage drop which permits the grid to follow the potential at the plate of V13. This constitutes an effective dc coupling which avoids any substantial loss of gain.

Note that the chopper-stabilized version of this power supply employs a 12AY7 in place of the 12AX7 for tube V13. Standard models include ballast regulator RT1 to maintain a stable 6.3 volts ac across the heater of V13. The ballast is not required in the chopper-stabilized version and the RT1 socket is therefore employed for the chopper-stabilizer unit with slight wiring changes shown on the schematic diagram.

3-8. DRIVER AMPLIFIER AND CATHODE FOLLOWER. This stage employs tube V10 in high gain, low current operation. Output is direct-coupled to the grids of cathode follower V9, which employs both sections of a dual-triode in parallel. Output from V9 is direct-coupled to the control grids of the series amplifiers, completing the regulator system loop.

3-9. CHOPPER STABILIZER. On units so equipped, the chopper stabilizer continuously corrects for zero offset in the balanced detector, thereby eliminating output drift from this cause. Connected across the grids of balanced input detector V13, the chopper stabilizer continually samples the offset at grid 2, chops it to produce a square wave, amplifies, rectifies, and filters it, and applies the resulting correction signal to grid 1 (pin 7) to reduce the net offset to a vanishingly small value. Without the chopper-stabilizer this stage is subject to drift to the extent that output voltage may change up to 0.1% or 50 millivolts for 8 hours. With chopper-stabilization, stability becomes 0.05% + 2 millivolts which represents a ten-to-fifty times improvement at low voltages where divider action by the control bridge makes zero offset, in an unstabilized system, the major source of drift. Because the chopper stabilizer adds gain of approximately 1000 to the regulator, and because it is unable to distinguish, as it were, between offset due to drift and offset to varying line or load conditions, regulation is improved to the figure shown in the Table of Specifications.

3-10. CURRENT LIMITER. The current limiter utilizes both sections of a type 12AX7 tube, a pnp transistor, and associated components. A resistor which develops a 4-volt drop at maximum rated current is inserted into the negative output line of the main dc supply to serve as a sampling resistor. One side of the resistor is connected to the grid of one section of the 12AX7 through the LIMITER CURRENT control. The signal at the cathode, pin 3, follows the voltage fluctuations sensed by the grid in an almost one-to-one correspondence, and this signal is applied at the emitter of the transistor. The base of the transistor is connected through a 10K limiting resistor to the other side of the sampling resistor. Thus the transistor operates with base-emitter potential which effectively equals the voltage drop across the sampling resistor. The resulting signal at the collector is applied to the grid of the second section of the tube, the cathode-follower output of which goes to the control grid of high gain amplifier V10.

When output current is below the limiter setting, the voltage drop across the sampling resistor is such that the emitter of the transistor is negative with respect to the base, and the transistor is therefore turned off. In this condition, the second cathode-follower tube section is turned sufficiently off so that it has no effect on tube V10.

When output current rises to the limiter setting, the emitter of the transistor becomes more positive with respect to the base. The transistor is thereby turned on and, by the same signal path previously described, takes control of tube V10, driving the regulator system to equilibrium at the current limiter setting.

3-11. OUTPUT CIRCUITRY. Capacitors C12 and C13 are connected across the output terminals to improve transient behavior, to lower the ac output impedance of the power supply, and to adjust the characteristic of the feedback regulator loop for stable operation. Also across the output is diode CR17 which protects the external load by presenting a low impedance to any reverse voltage that may develop when the unit is shut off. Neon glow lamps DS3 and DS4 serve as a clamp to protect internal reference tube V8 from voltage surges when the power supply is switched from a high to a low voltage in remote control (programmed) operation. DS3 and DS4 fire momentarily but are otherwise normally inoperative. It should be noted that throwing the LOCAL/REMOTE switch to REMOTE removes the positive side of the reference from the minus side of the high voltage output. This connection is re-established via the programming connections shown in Figure 2-2.

SECTION 4

MAINTENANCE

Attention is called to the Warranty under which this equipment is sold, to be found at the front of this manual.

4-1. PARTS REPLACEMENT. The electrical parts list and schematic diagram at the end of this book should be employed to identify all parts to be replaced. In general, replacement parts are completely defined by the values and tolerances indicated on the parts list. The following components, however, require special attention:

a. V3 through V8. Replacement of any of these tubes will affect null balance, which should therefore be readjusted as per paragraph 4-2.

b. V8. Replacement of this tube will change the internal reference voltage somewhat, and will necessitate recalibration as per paragraph 4-4.

c. DC CONTROL and VERNIER controls. If either of these wirewound potentiometers is defective, it is advisable to obtain an exact replacement. If none is available locally, an order should be addressed to the factory. Any temporary substitute potentiometer should provide an arc of 280° effective rotation for the panel dial markings to represent output correctly.

4-2. NULL ADJUSTMENT. The NULL control, located on the front panel, permits adjustment of the balanced input detector to null, or zero level. This adjustment, which holds over the entire operating range, is made as follows:

a. Remove the acorn nut covering the control.

b. With the DC CONTROL and VERNIER at zero, throw the LINE and DC switches on. (DC switch will not operate until time delay relay trips).

c. Connect a voltmeter across TP1 (J1) and the minus (—) REM post. Use 3-volt dc scale or lower.

d. Adjust the NULL control for zero on the meter. A very sensitive indication can be obtained by alternately connecting and disconnecting the meter lead.

4-3. NULL ADJUSTMENT FOR CHOPPER-STABILIZED UNITS. The NULL control on the chopper-stabilized version should be set to maximum resistance for optimum operation. No attempt should be made to adjust the NULL control to zero, as described above, with the chopper-stabilizer unit removed.

4-4. CALIBRATION. The CAL control, also found on the front panel, requires adjustment for any one of three reasons:

a. For close agreement between panel markings and output.

b. For exact 1000 ohms-per-volt ratio in programmed output.

c. For recalibration to either of the above upon aging or replacement of V8.

CAL control adjustment can be performed with either an accurate voltmeter or an external, precise voltage source.

4-5. If a voltmeter is employed, proceed as follows: (See Figure 4-1.)

a. Remove acorn nut covering CAL control. Connect meter across + and — terminals.

b. To calibrate panel markings turn VERNIER to zero and DC CONTROL to maximum panel marking. Place unit in operation and adjust CAL control for maximum voltage output of the power supply as indicated on the external voltmeter.

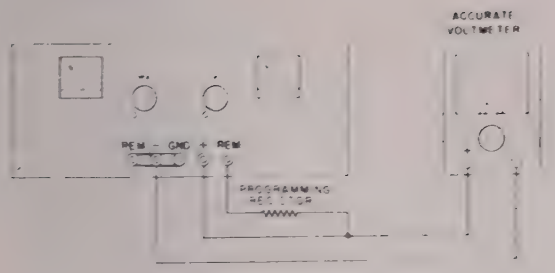


Figure 4-1. Calibration With Voltmeter for Exact 1000 Ohms-Per-Volt Programming

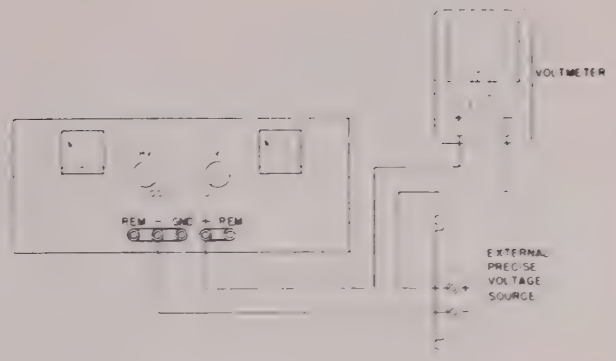


Figure 4-2. Calibration With External, Precise Voltage Source

c. To calibrate for exact 1000 ohms-per-volt programming constant, turn VERNIER and DC CONTROL to zero and set up the power supply for programmed operation using a programming resistor of the appropriate value to develop maximum output voltage. Place the unit in operation and adjust the CAL control for the maximum rated voltage of the power supply as indicated on the external meter.

4-6. If an external, precise source of voltage is employed, proceed as follows: (See Figure 4-2.)

a. Connect the negative outputs of the unit and the external voltage source together.

b. Connect a voltmeter between the positive terminals of the power supply and the external source.

c. Set the external source to exactly the maximum rated voltage output of the power supply.

d. To calibrate panel markings perform step c, turn VERNIER to zero and DC CONTROL to maximum panel marking. Place unit in operation and adjust CAL control for a zero reading on the external voltmeter. Use the lowest dc range available.

e. To calibrate for exact 1000 ohms-per-volt programmed output perform step c, turn VERNIER and DC CONTROL to zero, and set up the power supply for programmed operation using a programming resistor of the appropriate value to develop maximum output voltage. Place the unit in operation and adjust CAL control for zero on the external meter.

4-7. SERIES TUBE FAULTS. In selecting replacement series tubes, or when a malfunction appears to result from a faulty series tube, the following procedure is recommended:

a. Remove all series tubes but one.

b. Turn on unit, apply 1/N of full load current at a low voltage, where N = number of series tubes.

c. Check ripple and regulation.

d. Remove the remaining series tube, place another series tube in another socket, and repeat steps b and c. Repeat steps b and c for every other socket and tube, taking one at a time.

e. If one or more series circuits tests faulty, repeat the test in each case with a tube known to be satisfactory. If the repeated test proves favorable it may be assumed that the previous tube is defective. Otherwise the associated circuit should be checked for faults.

4-8. CLEANING AND LUBRICATION. This power supply employs forced air cooling. After extended service, therefore, considerable dust will be deposited on most surfaces within the unit. About twice a year the cover should be removed and all parts, and particularly the fan blades, should be cleansed free of dust and grime. Lubricate the fan motor once or twice a year by squeezing a few drops of light machine oil into the lubrication holes of the bearing straps.

4-9. TROUBLE SHOOTING. Referenced below are several symptoms of faults which could develop in this power supply. Opposite each symptom is the most likely cause and remedy. The table is intended as a guide to trouble shooting.

SYMPTOM	CAUSE	REMEDY
1. Unit is dead when LINE switch is thrown.	a. Fuse F1 blown or defective.	a. Replace F1.
2. Fuse F1 blows repeatedly.	a. Rectifiers CR1 thru CR7, CR9 thru CR11 and CR13 thru CR16 shorted.	a. Check rectifiers and replace if defective.
3. DC fuse F2 blows, output to zero.	a. Short circuit load.	a. Check load.
	b. Overload above current rating of power supply.	b. Check load.
	c. Fuse F2 defective, open.	c. Check for continuity and replace F2 if necessary.
	d. With load connected, DC CONTROL or VERNIER potentiometer is open.	d. Measure resistance of potentiometers. Refer to paragraph 4-1.
	e. With load connected, remote control line (programming line) is open.	e. Check remote control line for open.
	f. Diode CR17 shorted.	f. Replace CR17.
	g. Series amplifier tube (starting with V14) shorted with load connected.	g. Replace defective tube. Refer to paragraphs 4-1 and 4-7.
4. No control of output, voltmeter pins at top of scale.	a. Series amplifier tube (starting with V14) shorted.	a. Replace defective tube. Refer to paragraphs 4-1 and 4-7. Also check screen and cathode resistors of affected stage.
	b. Tube V10 defective.	b. Replace V10.
	c. DC CONTROL or VERNIER open.	c. Check and replace. Refer to paragraph 4-1.
	d. Programming resistor or line open, in programmed operation.	d. Check programming resistor and line.
5. No control of output, voltmeter at zero, and fuse F2 not blown.	a. Balanced input detector V13 defective.	a. Replace V13. Refer to paragraph 4-1.
	b. Ballast tube RT1 defective.	b. Replace RT1.
	c. Open filament on tube V9 or V13.	c. Replace V9 or V13.
6. Voltmeter indication disagrees with control settings at full scale.	a. Unit out of calibration.	a. Recalibrate.
7. Output voltage lower than control setting but recalibration impossible or out of CAL range.	a. Reference tube V8 has shifted voltage.	a. Replace V8. Refer to paragraph 4-1. Also recalibrate.
8. Output voltage lower than control setting in chopper-stabilized unit.	a. Tube (12AX7) in chopper-stabilizer unit defective.	a. Replace tube.

SYMPTOM	CAUSE	REMEDY
9. Poor line regulation.	a. Defective tube V3 through V8 or V13.	a. Replace defective tube. Refer to paragraph 4-1.
	b. Defective rectifier CR13, CR14, CR15, or CR16.	b. Replace defective rectifier.
10. Poor load regulation.	a. Poor load connections or high resistance in load leads.	a. Check load connections.
	b. Series amplifier tube (starting with V14) defective.	b. Replace defective tube. Refer to paragraphs 4-1 and 4-7.
	c. Chopper inoperative.	c. Replace chopper.
11. Excessive zero-offset (drift) in chopper-stabilized unit.	a. Tube V13 defective.	a. Replace V13.
	b. Chopper inoperative.	b. Replace chopper.
12. NULL adjustment impossible.	a. Fuse F2 blown.	a. Replace F2.
	b. Defective tube V3 through V8, V11, V12, or V13.	b. Replace defective tube.
13. High ripple.	a. In programmed operation, programming resistor or control line are coupling stray ac signal to power supply.	a. Shield programming resistor and/or control line.
	b. Defective tube V5, V6, V7, V8, V9, V10 or V13.	b. Replace defective tube.
	c. Defective capacitor C1, C2, C4, C5, C12, or C13.	c. Replace defective capacitor.
14. DC output changes abruptly at periodic rate.	a. Defective tube V3 through V8, V11 or V12.	a. Replace defective tube. Recalibrate if V8 is replaced.

4-10. VOLTAGE AND RESISTANCE TABLES. Voltage and resistance values in the table supplied with this manual are nominal and may vary as much as 20% among production units without causing difficulties. The conditions of measurement are as follows:

For resistance measurements:

a. Ac line cord not connected to power.

b. No load connected.

c. LINE and DC switches off. Floating output (swinging link disconnected from + or — post). LOCAL/REMOTE switch at LOCAL.

d. DC CONTROL and VERNIER at zero.

e. Readings from indicated tube pins to — (minus) output post.

For voltage measurements, using a 20,000 ohms-per-volt meter:

a. Line input 115 volts ac. LINE and DC switches on.

b. VERNIER at maximum and DC CONTROL at correct additive setting for maximum rated voltage output.

c. No load connected.

d. Floating output (swinging link disconnected from + or — output post). LOCAL/REMOTE switch at LOCAL.

e. Readings from indicated tube pins to — (minus) output post.

VOLTAGES

DATA NOT AVAILABLE AT TIME OF PUBLICATION

RESISTANCES

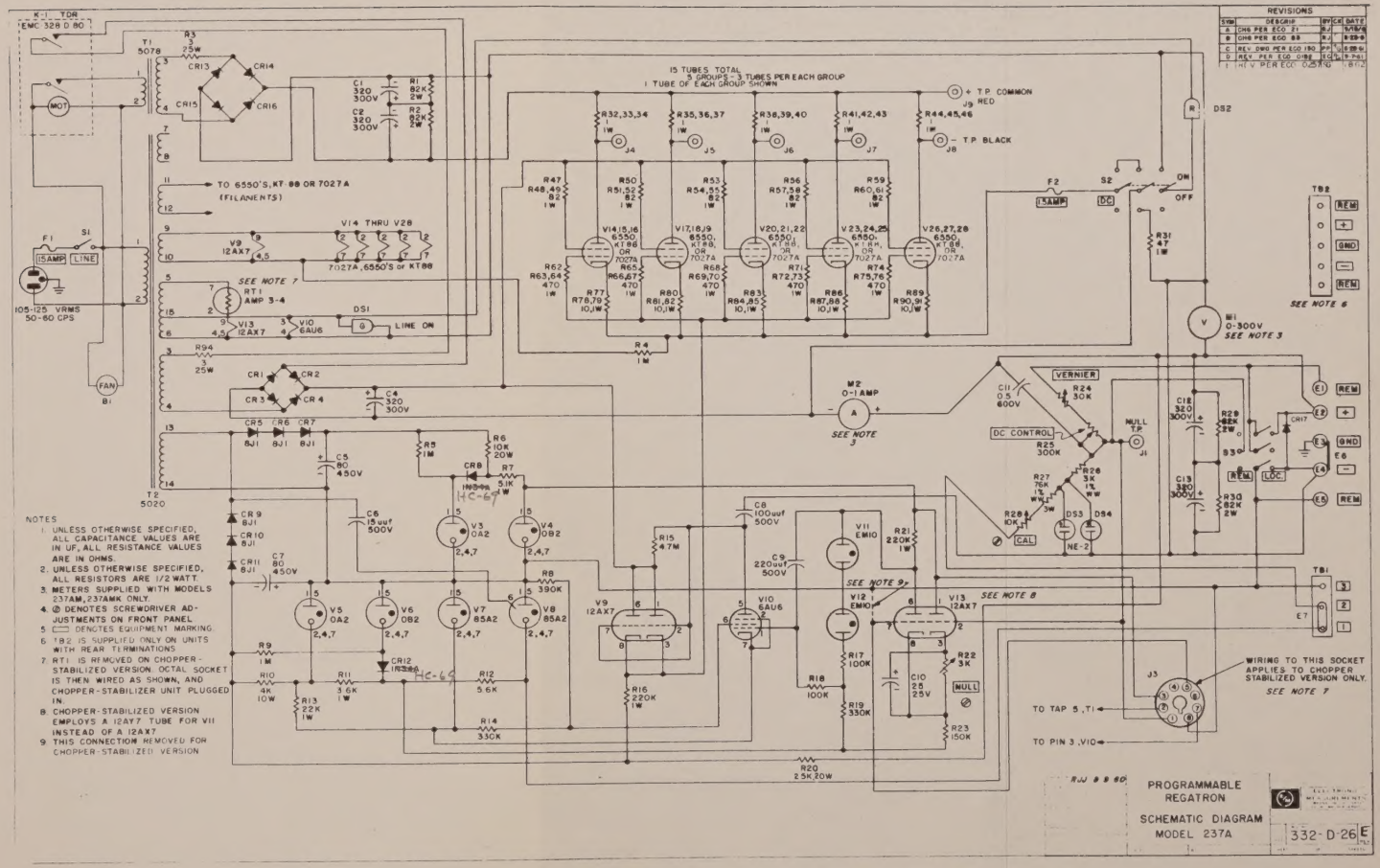
DATA NOT AVAILABLE AT TIME OF PUBLICATION

SECTION 5

PARTS LIST

REFERENCE SYMBOL	DESCRIPTION	TYPE OR PART NO.	MANUFACTURER
B1	Motor, shaded pole, 115V, 50-60 CPS, 6 in. fan blade	DYAB-570-3	Barber-Colman
C1, 2, 4, 12, 13	Capacitor, electrolytic, 320 UF, 300 VDC, insl. sleeve	D31962	Sprague
C5, 7	Capacitor, electrolytic, 80 UF, 450 VDC, insl. sleeve	D15911	Sprague
C6	Capacitor, mica, 15 UUF ±5%, 500 VDC	CM20B150J	Micamold
C8	Capacitor, mica, 100 UUF ±5%, 500 VDC	CM20B101J	Micamold
C9	Capacitor, mica, 220 UUF ±5%, 500 VDC	CM20B221J	Micamold
C10	Capacitor, electrolytic, 25 UF, 25 VDC, insl. sleeve	KE-25/25	Frako
C11	Capacitor, molded, paper, 0. 5 UF ±20%, 600 VDC	Type IMP-0. 5/600	Pyramid
	Line cord, 6'8" lg. #14 gauge 3 cond. , 3 prong plug	328-B-101	EMC
CR1-4, CR13-17	Rectifier silicon	CER71	Solitron
CR5,6,7, 9, 10, 11	Rectifier, selenium	8J1	Radio Receptor
CR8, 12	Diode, germanium	1N34A	Sylvania
DS1, 2	Lamp, 6. 3V, 0. 25A	44	G. E.
DS3, 4	Lamp, neon	NE-2	EMC
E1, 2	Post, binding, red	29-3R	Grayhill
E3, 4, 5	Post, binding, black	29-3B	Grayhill
E6	Shorting link	938-L	General Radio
E7	Shorting link	141-J	Cinch-Jones
F1	Fuse, cartridge, 15A	3AG15	Sightmaster
F2	Fuse, cartridge, 1. 5 A	3AG1. 5	Sightmaster
J1, 5-J9	Tip jack, nylon, black	105-603	E. F. Johnson
J3	Socket, octal (ballast tube or stabilizer unit)	9751-9	Eby
J4	Tip jack, nylon, red	105-602	E. F. Johnson
K1-TDR	Time delay relay, DPST	328-D-80	EMC
M1	Voltmeter, 0-300 VDC ±2% full scale	Model 653/V300	EMC
M2	Ammeter, 0-1 ADC ±2% full scale	Model 653/A1	EMC
R1, 2, 29, 30	Resistor, fixed, comp, 82K 10%, 2W	HB-8231	Allen-Bradley
R3	Resistor, fixed, WW, vitreous enamel, 3 ±5%, 25W	25F3	Ward Leonard
R4, 5, 9	Resistor, fixed, comp, 1 megohm ±10%, 1/2W	EB-1051	Allen-Bradley
R6	Resistor, fixed, WW, vitreous enamel, 10K ±5%, 20W	Type 'Brown Devil'	Ohmite
R7	Resistor, fixed, comp, 5100 ±5%, 1W	GB-5125	Allen-Bradley
R8	Resistor, fixed, comp, 390K ±10%, 1/2W	EB-3941	Allen-Bradley
R10	Resistor, fixed, WW, ceramic, 4K ±5%, 10W	10KT4K 'Koolohm'	Sprague
R11	Resistor, fixed, comp, 3600 ±5%, 1W	GB-3625	Allen-Bradley
R12	Resistor, fixed, comp, 5600 ±5%, 1W	GB-5625	Allen-Bradley
R13	Resistor, fixed, comp, 22K ±10%, 1W	GB-2231	Allen-Bradley
R14, 19	Resistor, fixed, comp, 330K ±10%, 1/2W	EB-3341	Allen-Bradley
R15	Resistor, fixed, comp, 4. 7 megohms ±10%, 1/2W	EB-4751	Allen-Bradley
R16, 21	Resistor, fixed, comp, 220K ±10%, 1W	GB-2241	Allen-Bradley
R17, 18	Resistor, fixed, comp, 100K ±10%, 1/2W	EB-1041	Allen-Bradley
R20	Resistor, fixed, WW, vitreous enamel, 25K ±5%, 20W	20F25000	Ward Leonard
R22	Resistor, variable, WW, 3000 ±5%, 2W, linear taper, 1/4 in. dia. , 1/8 in. lg. slotted shaft, series 43	CM18923	Clarostat
R23	Resistor, fixed, comp, 150K ±10%, 1/2W	EB-1541	Allen-Bradley
R24	Resistor, variable, WW, 30K ±5%, 3W, linear taper, 1/4 in. dia. , 1/2 in. lg. shaft, series 58	CM22196	Clarostat
R25	Resistor, variable, WW, 300K ±2%, 8W, linear taper, 3/8 in. dia. , insl. shaft	976-S11	General Radio
R26	Resistor, fixed, WW, 3000 ±1%, 1/2W	Type TX-178	Precision Resistor
R27	Resistor, fixed, 76K ±1%, 1/2W	Type P3-W	Precision Resistor
R28	Resistor, variable, WW, 10K ±5%, 2W, linear taper, 1/4 in. dia. , 1/8 in. lg. slotted shaft, series 43	CM18924	Clarostat
R31	Resistor, fixed, comp, 47 ±10%, 1W	GB-4701	Allen-Bradley

REFERENCE SYMBOL	DESCRIPTION	TYPE OR PART NO.	MANUFACTURER
R32-R46	Resistor, fixed, comp., 4.7 ±5%, 1W	GB-47G5	Allen-Bradley
R47-R61	Resistor, fixed, comp., 82 ±10%, 1W	GB-8201	Allen-Bradley
R62-76	Resistor, fixed, comp., 470 ±10%, 1W	GB-4711	Allen-Bradley
R77-R91	Resistor, fixed, comp., 10 ±10%, 1W	GB-1001	Allen-Bradley
R94	Resistor, fixed, WW, vitreous enamel, 3 ±5%, 25W	25F3	Ward Leonard
RT1	Ballast tube (237A)	Amp 3-4	Amperite
S1	Switch, toggle, SPST	160-73	Carling Electric
S2, 3	Switch, toggle, TPDT	HL233-73	Carling Electric
T1	Transformer, power	5078	EMC
T2	Transformer, filament & power	5020	EMC
TB1	Barrier strip, 3 terminal	3-141-Y	Cinch-Jones
TB2	Barrier strip, 5 terminal (rear termination only)	5-141-Y	Cinch-Jones
V3, 5	Electron tube	OA2	RCA
V4, 6	Electron tube	OB2	RCA
V7, 8	Electron tube	85A2/OG3	Amperex
V9	Electron tube	12AX7	RCA
V10	Electron tube	6AU6	RCA
V11, 12	Electron tube	EM10	EMC
V13	Electron tube (237A)	12AX7	RCA
V13	Electron tube (237AK)	12AY7	G.E.
V14-V28	Electron tube	6550 or	Tung-Sol
		KT88	British Ind.
XDS1	Holder assembly, pilot lamp, green faceted lens	100	Drake
XDS2	Holder assembly, pilot lamp, red faceted lens	100	Drake
XF1, 2	Extractor post, fuse, miniature	342003	Littelfuse
XV3-XV8, XV10	Socket, 7 pin, miniature	53P24022	Cinch-Jones
XV9, 13	Socket, 9 pin, noval	14502	Cinch-Jones
XV14-XV28	Socket, 8 pin, octal	9751-9	Eby


REVISIONS
SYM DESCRIP BY CK DATE
A CHG PER ECO 21 RJ 9/15/59
B CHG PER ECO 88 RJ 9-23-60
C REV DWG PER ECO 190 PT 5-23-61
D REV PER ECO 0198 TCS 9-7-61
1 H.V. PER ECO 0.2.5.7.6.6 CB12
K-1 TDR EMC 328 D 80
T1 5078
T2 5020
MOT
FAN B1
F1 15AMP LINE
S1
105-125 VRMS 50-60 CPS
TO 6550'S, KT 88 OR 7027A (FILAMENTS)
V9 12AX7
V14 THRU V28 7027A, 6550'S or KT88
SEE NOTE 7
RT1 AMP 3-4
V13 12AX7
V10 6AU6
DS1 LINE ON
15 TUBES TOTAL 5 GROUPS - 3 TUBES PER EACH GROUP 1 TUBE OF EACH GROUP SHOWN
+ T.P. COMMON RED
- T.P. BLACK
J4 J5 J6 J7 J8 J9
R32,33,34 R35,36,37 R38,39,40 R41,42,43 R44,45,46
V14,15,16 6550, KT88 OR 7027A
V17,18,19 6550, KT88 OR 7027A
V20,21,22 6550, KT88 OR 7027A
V23,24,25 6550, KT88 OR 7027A
V26,27,28 6550, KT88 OR 7027A
F2 1.5AMP
S2 DC ON OFF
DS2
R31 47 1W
M1 0-300V SEE NOTE 3
M2 0-1 AMP SEE NOTE 3
VERNIER
DC CONTROL
NULL T.P.
J1
CAL
DS3 DS4 NE-2
TB2 REM + GND - REM SEE NOTE 6
TB1 3 2 1 E7
J3
WIRING TO THIS SOCKET APPLIES TO CHOPPER STABILIZED VERSION ONLY. SEE NOTE 7
TO TAP 5, T1
TO PIN 3, V10
V11 EM10
V12 EM10 SEE NOTE 9
V13 12AX7 SEE NOTE 8
V9 12AX7
V10 6AU6
V3 0A2
V4 0B2
V5 0A2
V6 0B2
V7 85A2
V8 85A2
CR12 HC-69
HC-67
NOTES
1. UNLESS OTHERWISE SPECIFIED, ALL CAPACITANCE VALUES ARE IN UF, ALL RESISTANCE VALUES ARE IN OHMS.
2. UNLESS OTHERWISE SPECIFIED, ALL RESISTORS ARE 1/2 WATT.
3. METERS SUPPLIED WITH MODELS 237AM, 237AMK ONLY.
4. Ø DENOTES SCREWDRIVER ADJUSTMENTS ON FRONT PANEL.
5. ▭ DENOTES EQUIPMENT MARKING.
6. TB2 IS SUPPLIED ONLY ON UNITS WITH REAR TERMINATIONS.
7. RT1 IS REMOVED ON CHOPPER-STABILIZED VERSION. OCTAL SOCKET IS THEN WIRED AS SHOWN, AND CHOPPER-STABILIZER UNIT PLUGGED IN.
8. CHOPPER-STABILIZED VERSION EMPLOYS A 12AY7 TUBE FOR V11 INSTEAD OF A 12AX7.
9. THIS CONNECTION REMOVED FOR CHOPPER-STABILIZED VERSION
PROGRAMMABLE REGATRON
SCHEMATIC DIAGRAM
MODEL 237A
332-D-26 E

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